Comments and Addenda

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Photoproduction of Positive Pions from ^{3}He

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Differential cross sections for the reaction $^3\text{He}(\gamma,\pi^+)^3\text{H}$ have been calculated under the impulse-approximation theory, using two different types of wave functions. The parameters of these wave functions are obtained from a variational calculation of the binding energy for the trinucleons, using a central velocity-dependent potential. Though the cross sections calculated using a modified Feshbach wave function are found to be in reasonable agreement with those obtained from the experiments by O'Fallon *et al.*, the discrepancies reflect the inadequacy of the simplified impulse-approximation theory in our calculation.

THREE years ago O'Fallon *et al.*[1] studied the reaction

$$\gamma+{}^3\text{He}\rightarrow\pi^++{}^3\text{H} \tag{1}$$

experimentally. Using the impulse approximation, they have also derived the differential cross section for the reaction (1) in the form

$$(d\sigma/d\Omega)({}^3\text{He})=\Phi[d\sigma/d\Omega(p)]\,|F(q^2)|^2. \tag{2}$$

In Eq. (2), Φ is the kinematic factor, $d\sigma/d\Omega(p)$ is the cross section for photoproduction from a free proton, and $F(q^2)$ is the nuclear form factor for ^{3}H or ^{3}He, if their ground-state spatial wave functions are identical.

Taking appropriate values of Φ and $d\sigma/d\Omega(p)$ and the values of $F(q^2)$ as obtained in the electron-trinucleon scattering experiments, O'Fallon *et al.*[1] have calculated the cross section $d\sigma/d\Omega(^3\text{He})$ from Eq. (2). They have found that the cross sections obtained in their experiment lie from 25 to 50% below the values predicted from the impulse-approximation theory as given above. They also remarked that, by calculating $F(q^2)$ from the Gunn-Irving wave function,[2] whose parameter was taken to be consistent with the photodisintegration value of Berman *et al.*,[3] the agreement became worse.

The following two wave functions are chosen here to describe the ground states of either ^{3}He or ^{3}H:

The modified Feshbach wave function[4]

$$\psi=N\{\exp[-\tfrac{1}{2}\alpha(r_{12}+r_{13}+r_{23})]+A\exp[-\tfrac{1}{2}\lambda(r_{12}+r_{13}+r_{23})]\}, \tag{3}$$

or the modified Irving wave function[5,6]

$$\psi=\frac{N\{\exp[-\alpha(r_{12}^2+r_{13}^2+r_{23}^2)^{1/2}]+A\exp[-\lambda(r_{12}^2+r_{13}^2+r_{23}^2)^{1/2}]\}}{(r_{12}^2+r_{13}^2+r_{23}^2)^n}. \tag{4}$$

The parameters of these wave functions are obtained from variational calculations of the binding energy of the trinucleons using a central velocity-dependent potential.[4-6] The best values of the parameters are

$$\alpha=0.732\ \text{fm}^{-1},\quad \lambda=1.415\ \text{fm}^{-1},\quad A=-1.305, \tag{5}$$

and

$$\alpha=0.70\ \text{fm}^{-1},\quad \lambda=1.23\ \text{fm}^{-1},\quad A=-1.20,\quad n=0 \tag{6}$$

for the wave functions (3) and (4), respectively. With these values of the parameters, both wave functions give the binding energy, rms radius, integrated and bremsstrahlung-weighted photodisintegration cross sections, and the bare form factor of trinucleons in reasonable

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[2] J. C. Gunn and J. Irving, Phil. Mag. **42**, 1353 (1951).

[3] B. L. Berman, L. J. Koester, and J. H. Smith, Phys. Rev. **133**, B117 (1964).

[4] B. K. Srivastava, Nucl. Phys. **67**, 236 (1965).

[5] S. C. Jain and B. K. Srivastava, J. Phys. **A2**, 214 (1969).

[6] S. C. Jain and B. K. Srivastava, J. Phys. **A1**, 558 (1968).

agreement with experiments and with the values obtained from hard-core potentials.[4–8] However, the agreement with experiment of these properties for wave function (4) is much better than is that obtained with wave function (3). For a comparative study, Table I shows the values of the binding energy and the rms radius of triton and the Coulomb energy of ^{3}He obtained with these wave functions, along with the experimental values.[5]

Levinger and Srivastava[8] and Jair and Srivastava[5] calculated $F(q^2)$ for the above wave functions using the analysis of Schiff,[9] with the parameter values given by (5) and (6), respectively. The values of $d\sigma/d\Omega(p)$ are taken from the theory of Chew *et al.*[10] (tabulated in Ref. 1), and Φ is taken to be 1.65, because it will remain practically constant over the energy region considered here.[1] Using the above values, we have estimated the

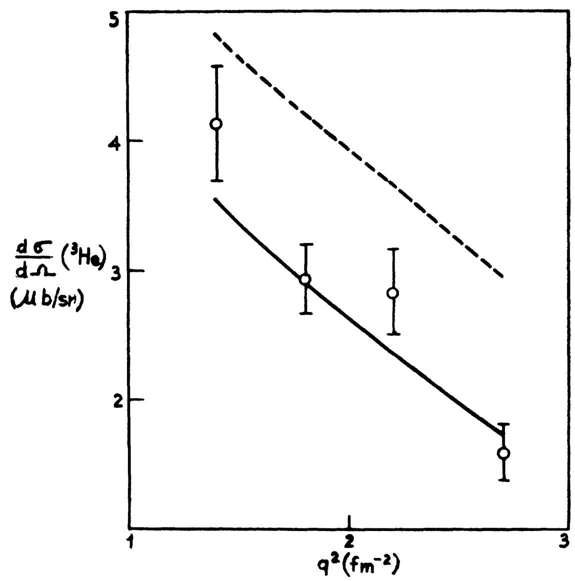

FIG. 1. The differential cross section (in the c.m. system) for the photoproduction of π^+ from ^{3}He plotted against the momentum transfer squared q^2, at a triton angle of 35° (in laboratory system) and incident photon energy between 182 and 252 MeV (in laboratory system). The solid and the dashed curves show our calculated results using the modified Feshbach and modified Irving wave functions, while the circles corresponds to the experimental values of O'Fallon *et al.* (Ref. 1).

TABLE I. Binding energy and rms radius of the triton and the Coulomb energy of ^{3}He.

	Binding energy (^{3}H) (MeV)	Coulomb energy (^{3}He) (MeV)	rms radius (^{3}H) (fm)
Modified Feshbach wave function	7.17	0.663	1.92
Modified Irving wave function	8.22	0.724	1.68
Experimental	8.49	0.764	1.64

differential cross section $d\sigma/d\Omega(^3\text{He})$ in the c.m. system at a triton angle of 35° in the laboratory system and with the photon energy varying between 182 and 252 MeV in the laboratory system.

Figure 1 shows our calculated differential cross sections for both wave functions along with the experimental results of O'Fallon *et al.*[1] It is quite obvious from the figure that our calculated cross sections for the modified Feshbach wave function are in reasonable agreement with experiments, as compared to the results obtained from the modified Irving wave function. This is contrary to the fact mentioned earlier that the modified Irving wave function is superior to the modified Feshbach wave function in explaining various other features of trinucleons. The main cause seems to lie in the inadequacy of the simplified impulse approximation adopted by O'Fallon *et al.*[1] As already stated, O'Fallon *et al.*[1] have also pointed out that the cross sections obtained in their experiment lie from 25 to 50% below the values predicted by this theory with form factors from electron scattering data. Our modified Feshbach wave function yields lower values of the nuclear form factor than those obtained from our modified Irving wave function; hence, we get reasonable agreement with experiment for the calculated differential cross section for the reaction $^3\text{He}(\gamma, \pi^+)^3\text{H}$ using the modified Feshbach wave function. We can, therefore, conclude that neither of the above wave functions can explain simultaneously the photoproduction cross sections of pions from ^{3}He with the impulse-approximation theory, and the various other nuclear properties (i.e., binding energy, rms radius, integrated and bremstrahlung-weighted photodisintegration cross sections and the bare form factor).

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